

(21) (A1)	2,102,374
(22)	1993/11/03
(43)	1994/05/06

5,083,4/67

(51) INTL.CL.<sup>5</sup> D21F-001/02; D21F-001/06; D21F-001/08

(19) (CA) **APPLICATION FOR CANADIAN PATENT** (12)

(54) Method of Making Paper

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(30) (DE) P 42 37 304.2 1992/11/05  
(DE) P 42 39 845.2 1992/11/27

(57) 12 Claims

Notice: This application is as filed and may therefore contain an incomplete specification.

**Canada**

CCA 3254 (10-92) 41 7530-21-936-3254

## METHOD OF MAKING PAPER

The invention is directed to a method of making adjustments at the headbox of a web-forming machine, such as a paper machine, to provide a web of relatively uniform density and layer height.

A headbox for a paper machine should adjust the pulp density and fiber orientation profile of the paper pulp suspension, at the latest, before the suspension passes through the discharge slit of the headbox, so that the pulp density and fiber orientation profiles of the paper web correspond to the desired requirements over the entire width of the web, meaning, as a rule, that they are constant.

When operating a paper machine, there are many perturbing factors which hinder the achievement of the two above requirements. These perturbing factors include, for example, temperature and pressure fluctuations, manufacturing tolerances, and defects in the design or adjustment of the paper machine for the production process after the paper pulp is discharged from the headbox.

The following state of the art has become known for influencing the transverse profile of a paper web. German publication DE 35 14 554 proposes to change the pulp density locally; that is, to adjust the pulp density at certain points, depending on demand. However, it is not described how this should be accomplished.

German publication DE 40 19 593 A1 recommends that, upon deviation of the pulp density profile of the paper web at a certain point of the web width, the concentration  $C_M$  of the respective section flow, and thus that of the flow leaving the respective mixer, should be changed correspondingly. In order to achieve this, the ratio of the amounts of control flows  $Q_N/Q_L$ , introduced to the mixture are changed. However, in the case of valves of the usual construction, it is difficult to avoid deviation of the section flow  $Q_M$  leaving the mixer from the required value in an uncontrolled and unwanted manner.

In addition, it is known from German publication DE-OS 35 38 466 that a change of the volume flow of a section leads to influencing the fiber orientation angle in the discharge section of the headbox. If a section flow deviates from the required value in an uncontrolled manner, the fiber orientation will also change in an uncontrolled manner.

Furthermore, it is known from German publications DE 29 42 966 and DE-OS 35 35 849 that one can change the width of the discharge slit, for example, with threaded spindles for horizontally swinging or bending the upper lip. As a result, the throughput of the suspension can be altered locally. However, at the same time, the flow direction is also influenced locally, and thus the fiber orientation is affected. Namely, at the narrow parts of the discharge slit, the fibers will be disposed in a different flow direction than at the other parts of the discharge slit. This

means that, although the consistency can be made uniform over the width of the headbox by this method of control, called displacement control, the originally good fiber orientation is destroyed.

5        It can be seen from the state of the art described above that there are essentially two parameters that are adjusted at the headbox, namely the flow rate of the paper stock suspension at a given point of the headbox and the stock consistency, and that those two  
10 parameters have a different and conflicting influence on the stock density profile and fiber orientation.

      The present invention is directed to a method of making adjustments at the headbox of a web-forming  
15 machine to provide a web of relatively uniform density and layer height. The headbox has a plurality of transverse sections, each of which is provided with a web material at a variable flow rate and a variable consistency. The method includes the steps of  
20 measuring the layer height transverse profile of the web at a point along the web, measuring the density transverse profile of the web at a point along the web, and comparing a portion of the layer height profile with a corresponding portion of the density profile to  
25 determine whether there are corresponding deviations in the profiles.

      If there is a deviation in the density profile without a corresponding deviation in the layer height profile, then the magnitude of the consistency of the  
30 web material provided to the transverse section of the

headbox associated with the deviation is changed in a direction opposite the sign of the deviation.

If there is a deviation in the layer height profile without a corresponding deviation in the  
5 density profile, then the magnitude of the flow rate of web material provided to the transverse section of the headbox associated with the deviation is changed in a direction opposite the sign of the deviation.

If there is a deviation in the density profile  
10 with a corresponding deviation with the same sign in the layer height profile, then the magnitude of the flow rate of the web material provided to the transverse section of the headbox associated with the deviations is changed in a direction corresponding to  
15 the sign of the deviations.

The web is preferably dewatered by providing it to a dewatering apparatus, pressed and dried to provide a finished web, and rolled into a roll. The method may be used in connection with a paper machine to form a  
20 paper web.

Instead of measuring the layer height profile, the fiber orientation profile of the web may be measured, and adjustments in the consistency and flow rate of the web material may be made based on the presence or  
25 absence of corresponding deviations in the measured fiber orientation and density profiles.

The invention is based on the inventors' recognition that there are two parameters that fundamentally influence the density profile, namely the  
30 consistency and the flow rate of the web material at a given point of the headbox, and that the fiber

orientation of the web material is generally influenced only by the flow rate of the web material at a given transverse point or section of the headbox.

These and other features and advantages of the present invention will be apparent to those of ordinary skill in the art in view of the detailed description of the preferred embodiment, which is made with reference to the drawings, a brief description of which is provided below.

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Fig. 1 is a schematic illustration of a preferred embodiment of a paper machine in accordance with the present invention; and

Fig. 2 illustrates a density profile and a layer height profile of a paper web generated by the paper machine of Fig. 1.

Fig. 1 is a schematic illustration of a paper machine 10 with a headbox 12 on the left side, which is fed with a web material such as paper pulp, or stock suspension, across a plurality of transverse sections. The magnitude of the flow of stock suspension provided to each transverse section is regulated with a valve  $V_2$ . The consistency of the stock suspension provided to each transverse section is determined by the combination of two stock flows at a mixer  $m_1$ , one having a maximum consistency  $b_{max}$  and the other having a minimum consistency  $b_{min}$ . The actual consistency is

determined by a valve  $V_1$ , which controls the magnitude of the stock flow with the minimum consistency  $b_{\min}$ .

In the operation of the paper machine 10, the headbox 12 displaces the stock suspension onto a screen 14 for dewatering the stock suspension. The screen 14 is translated past the headbox 12 from left to right in Fig. 1 via a plurality of rollers 16. The point at which the velocity of the impinging stock suspension is adjusted to the screen velocity is designated with  $S$ . At this point, the stock layer height is  $h_i$ , where  $i$  represents a particular transverse portion of the stock suspension, i.e. a particular portion along the width of the web. It should be understood that the layer height of the stock suspension may be different at different transverse points  $h_i$  of the suspension.

The end of the dewatering section of the screen 14 is designated by  $S_1$ , which is then followed by a conventional pressing and drying apparatus 18. After the stock suspension is pressed and dried, at a point  $S_2$ , it is wound up on a roll 20 as paper.

The consistency of the stock suspension at a transverse point  $i$  of the headbox 12 is designated herein as  $b_i$ , and the amount or flow rate of the stock suspension introduced at a transverse point  $i$  of the headbox 12 is designated as  $q_i$ .

After the stock suspension is ejected onto the moving screen 14, the velocity of the stock suspension adjusts to the velocity of the screen 14 at a point  $S$ , at which point those two velocities are substantially the same. At that point  $S$ , the flow rate of the stock

suspension is proportional to the layer height  $h_i$  of the stock suspension. If the velocity of the screen 14 is known, the flow magnitude of the stock suspension can be determined by measuring the layer height  $h_i$  and multiplying it by the screen velocity.

The layer height  $h_i$  can be determined in any conventional manner, such as by a plurality of sensors (not shown), each of which is provided at a different transverse section of the screen 14. The mean or average layer height value  $h_{av}$  is determined by dividing the sum of all the layer height measurements  $h_i$  by the number of such measurements.

The density of the stock suspension at a transverse point  $i$  is designated herein as  $f_i$ . That density  $f_i$ , which may be represented for example, in grams/square meter (GSM), can be measured in a conventional manner by a plurality of sensors (not shown), each of which is provided at a different transverse section of the screen 14, at a position between the points  $S_1$  and  $S_2$  along the length of the stock suspension.

After the stock density  $f_i$  at each such point is measured, the average stock density  $f_{av}$  may be determined by dividing the sum of all the transverse density measurements  $f_i$  by the number of such measurements.

As described below, the consistency  $b_i$  of the stock suspension and the stock flow rate  $q_i$  are controlled via the valves  $V_1$  and  $V_2$ , respectively, based



upon the measurements of the layer height  $h_i$  and the stock density  $f_i$ .

Referring to Fig. 2, a stock density transverse profile  $f'_i$  is shown above a layer height transverse profile  $h'_i$ . Each point  $h'_i$  on the layer height profile is determined from the measurements described above in accordance with the following equation:  $h'_i = (h_i - h_{ave})/h_{ave}$ . Similarly, each point  $f'_i$  on the stock density profile is determined from the measurements made above in accordance with the following equation:  $f'_i = (f_i - f_{ave})/f_{ave}$ .

The stock density  $f'_i$  is shown to increase above the average stock density at a transverse point A of the paper machine and to decrease below the average stock density at a transverse point B. At other points on the density profile, the stock density  $f'_i$  is shown to be approximately equal to the average stock density.

The layer height  $h_i$  is shown to increase above the average layer height at the transverse point A and to decrease below the average layer height at a transverse point C. At other points on the layer height profile, the layer height  $h'_i$  is shown to be about equal to the average layer height.

It should be noted that, since both the layer height  $h'_i$  and stock density  $f'_i$  both increased at the same transverse point A of the paper machine, there is a high correlation between the layer height and stock density at that point A. Here, one would expect defective fiber orientation and a high density deviation. In order to correct such condition, the

flow rate  $q_i$  is decreased in the region  $i = A$  via the valve  $V_2$  associated with the transverse point A of the headbox 12.

It should be noted that, at transverse point B of Fig. 2, there is only a deviation in the density  $f'_i$ , with no corresponding deviation in the layer height  $h'_i$ . In this case, the deviation in the density  $f'_i$  is corrected by adjusting the valve  $V_1$  associated with the transverse point B of the headbox 12 so that less of the stock solution having the consistency  $b_{\min}$  is provided to the headbox 12.

At transverse point C, there is a deviation in the layer height  $h'_i$ , but no deviation in the density profile  $f'_i$ . In this case, in order to avoid undesirable fiber orientation, the flow rate  $q_i$  at the transverse point C is increased by adjusting the valve  $V_2$  associated with the transverse point C and, at the same time, reducing the stock consistency at the transverse point C by adjusting the valve  $V_1$  so that more stock solution having the consistency  $b_{\min}$  is provided to the mixer  $m_1$  associated with the transverse point C.

In general terms, by determining the deviations in the layer height profile  $h'_i$  and the stock density profile  $f'_i$  and whether the deviations correspond with each other, one can determine which of the parameters  $q_i$  or  $b_i$  to adjust in order to achieve a uniform stock density profile and layer height profile.

More specifically, the method of control includes the steps of determining the layer height transverse

profile of the web at a point along the web,  
determining the density transverse profile of the web  
at a point along the web, and comparing a portion of  
the layer height transverse profile with a  
5 corresponding portion of the density transverse profile  
to determine whether there are corresponding deviations  
in the profiles.

If there is a deviation in the density transverse  
profile without a corresponding deviation in the layer  
10 height profile, then the magnitude of the consistency  
of the web material provided to the transverse section  
of the headbox associated with the deviation is changed  
in a direction opposite the sign of the deviation.  
Thus, at transverse point B of Fig. 2, where the sign  
15 of the deviation is negative, i.e.  $f'$ , decreased, the  
change in consistency is made positive, i.e. the  
consistency is increased in response.

If there is a deviation in the layer height  
profile without a corresponding deviation in the  
20 density profile, then magnitude of the flow rate of web  
material provided to the transverse section of the  
headbox associated with the deviation is changed in a  
direction opposite the sign of the deviation. Thus, at  
transverse point C of Fig. 2, where the sign of the  
25 deviation is negative, i.e.  $h'$ , decreased, the change  
in flow rate is made positive, i.e. the flow rate is  
increased in response.

If there is a deviation in the density profile  
with a corresponding deviation with the same sign in  
30 the layer height profile, then the magnitude of the

flow rate of the web material provided to the transverse section of the headbox associated with the deviations is changed in a direction opposite the sign of the deviations. Thus, at transverse point A of Fig. 2, where the signs of the deviations are the same, i.e. both  $f'_i$  and  $h'_i$  increased, the change in flow rate is changed in the opposite direction, i.e. the flow rate is decreased in response.

In the control method, if there is a deviation in the density transverse profile with a corresponding deviation in the layer height profile of opposite sign, then both deviations may be treated separately as uncorrelated deviations.

Also, counter-control may be carried out with the other parameters of the change that was performed. As used herein, the "counter-control" refers to a type of control in which the mathematical product of the stock flow rate and stock consistency is held substantially constant. Thus, if the stock flow rate is increased, the stock consistency would be decreased by an amount so that the product of the two remained constant. If the stock flow rate is decreased, the stock consistency would be increased by an amount to maintain the product of the two constant.

In another preferred method in accordance with the invention, instead of measuring the layer height profile of the web, the fiber orientation profile is measured at a point along the web. The fiber orientation can be measured by any conventional manner, such as by ultrasound or with the aid of a laser.

The remaining steps are similar to the first method described above. In particular, after the fiber orientation profile and the density profile of the web are measured, a portion of the fiber orientation  
5 profile is compared with a corresponding portion of the density profile to determine whether there are corresponding deviations in the two profiles.

If there is a deviation in the density profile without a corresponding deviation in the fiber  
10 orientation profile, then the magnitude of the consistency of the web material provided to the transverse section of the headbox associated with the deviation is changed in a direction opposite the sign of the deviation. If there is a deviation in the fiber  
15 orientation profile without a corresponding deviation in the density profile, then the magnitude of the flow rate of web material provided to the transverse section of the headbox associated with the deviation is changed in a direction opposite the sign of the deviation. If  
20 there is a deviation in the density profile with a corresponding deviation with the same sign in the fiber orientation profile, then the magnitude of the flow rate of the web material provided to the transverse section of the headbox associated with the deviations  
25 is changed in a direction opposite the sign of the deviations.

The above methods can be applied to all types of headboxes, for example, one layer headboxes, multi-layer headboxes, headboxes for slit formers, headboxes  
30 for long sieves, etc.

The above methods could be carried out via any conventional control scheme. For example, a conventional proportional-integral (PI) or proportional-integral-derivative (PID) controller could  
5 be provided for each transverse section of the stock solution. Each controller would be connected to receive both the inputs from the sensors which measure the stock density and layer height at its transverse point or section, and each controller would be  
10 connected to control both the valves  $V_1$  and  $V_2$  associated with its transverse section.

Alternatively, a single controller could be connected to the transversely located sensors for sensing the density and layer height of the web and to  
15 the transversely located valves for controlling the stock consistency and flow rate. In the case of a single controller, the control method could be accomplished on a time-shared or round-robin basis, with each transverse section of the paper machine being  
20 controlled sequentially.

Modifications and alternative embodiments of the invention will be apparent to those skilled in the art in view of the foregoing description. This description is to be construed as illustrative only, and is for the  
25 purpose of teaching those skilled in the art the best mode of carrying out the invention. The details of the structure and method may be varied substantially without departing from the spirit of the invention, and the exclusive use of all modifications which come  
30 within the scope of the appended claims is reserved.

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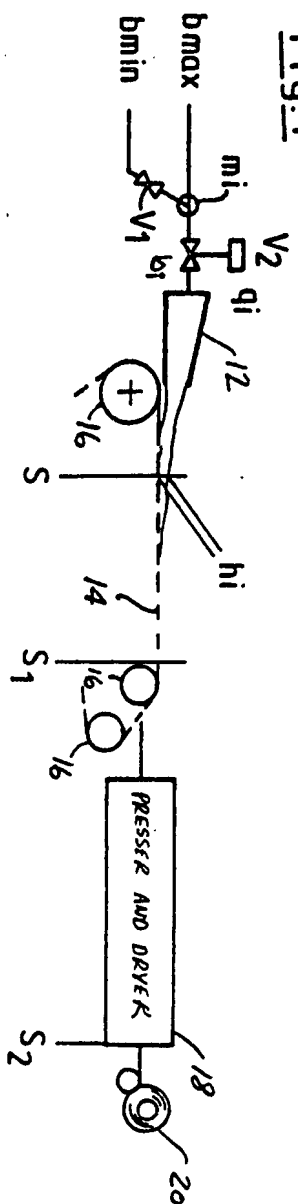


Fig. 2

